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A CRITIQUE OF ANALYTIC WAR GAMING AS AN AID TO THE MILITARY DECISIONMAKER

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A CRITIQUE OF ANALYTIC WAR GAMING
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THE MILITARY DECISIONMAKER

by

Robert A. McCaffery

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
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ABSTRACT

In the modern analytic war game, a military situation is simulated by describing the conflict in a mathematical model and carrying out the "play" of the game by computer. The traditional methods of tactical analysis are blended with the relatively new methods of mathematical simulation.

This thesis has been written with the purpose of familiarizing the military officer with this new and promising analytic tool.

Internal features of the game, which should be understood and appreciated by the military beneficiary of war game results, are examined. These include mathematical approximations, assumptions, and simulated decisions using the Monte Carlo technique. Some guidelines are suggested to assist the user in determining the meaning and relevancy of war game results. The objectives, appropriate uses, advantages, and disadvantages of this analytic technique are discussed from the point of view of the game's usefulness to the military decisionmaker.

PREFACE

The analytic war game, usually played on a high speed digital computer, is becoming an accepted, though controversial, aid to the military decisionmaker. The purpose of this thesis is to attempt to collect and condense information about, and assess the usefulness of, this relatively new approach to military analysis.

It is intended that the treatment of the subject will take the point of view of looking at the value of this technique to the military planner who must make use of all available methods of analysis, even though he may not have had an opportunity to explore each method in depth.

The ideas and opinions distilled in this report have been drawn from current literature in the field, from formal courses in war gaming, and most profitably, from conversations with military officers deeply concerned with uses and misuses of analytic methods, and civilian operations researchers who are involved in the solution of military problems.

The author is indebted to Professor Alvin F. Andrus for his expert guidance during the preparation of the thesis and to Professor Rex H. Shudde for his thoughtful review of the final draft.

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CHAPTER I

INTRODUCTION

1. Purpose

The purpose of this thesis is to present to the military officer a critique of analytic war gaming in light of its contribution to the knowledge of modern military strategy and tactics. While this subject has been explored extensively, there does not seem to be much formal dialogue directed to the military decisionmaker, who must make operational decisions based on results of mathematical analysis. The understanding and appreciation of each analytic method is essential to the making of better military plans in a volatile world situation. This paper is an attempt to partially fill this gap as regards the particular methodology of war game analysis.

2. Concepts and terms

In any mathematical analysis, it is assumed, or at least believed, that the relations involved in the real system can somehow be quantified and abstracted. This abstraction is called a model, whether it be a simple addition equation or a series of complex formulae attempting to describe interactions between nucleons. The model has been described as a symbolic representation of the domain of phenomenon under investigation (5).

Simulation. In military war gaming, this symbolic representation, or model, is a mathematical image of the military setup that we are trying to learn more about. We can vary the quantities in the model and develop a series of configurations which might suggest a picture of the model in natural motion. By doing so, we simulate or capture the appearance of the real system being investigated. When the con-

flict or engagement is "played out" we say that the action is being simulated.

There are many types of simulation: wind tunnels, link trainers, physical models, etc., but the term as used here will imply a computer play of a military conflict situation.

A simulation must also be distinguished from a computer solution to a definite, but lengthy, numerical problem. Many solutions to linear programming problems, for example, are carried out entirely by computer. A simulation, on the other hand, implies some complex entity which is in motion and the results of such motion are not uniquely determined, as they would be in a solution to a static mathematical problem. The link trainer, for example, is meant to simulate a real aircraft, but each time it is used the results are different and may or may not compare well with the results of an actual flight by the same pilot.

War games. When the concept of an opposing force capable of making decisions is introduced, the simulation becomes a game. During the play of the game, decisions made by the enemy may be predetermined or chosen randomly, but they will still be considered essentially as actions by a rational enemy.

Unless modified, e.g., manual war game, the phrase war game will be used synonymously with the term simulation in this thesis.

3. Types of war games.

The war game has a long history as an aid in planning military operations and as a method of gaining insight into possible future military engagements (32). War gaming, in general, can be divided according to the two purposes for which it is employed. Although

these purposes will overlap in any given game, one will usually be given as the primary reason for formulating the game originally.

One purpose has been for the training of the decisionmaker. This type of game could be played through, allowing a prospective leader to make all the decisions necessary to the success of the campaign, thereby gaining experience that he might never get until such time when errors in judgment would be far more costly. In recent times, this use of the game as a training device has become an elaborate and sophisticated method of training executives in industry as well as future admirals and generals. Many computer assisted business games have proved beneficial to men who already hold positions as responsible decisionmakers (2). In the Navy, the Naval Electronic Warfare Simulator (NEWS) at the Naval War College is contributing to the decisionmaking ability of many Naval Officers (15). These games create an artificial atmosphere in which decisions can be made which closely resemble, in form, the actual decisions which must be made in the real world. War games used in this regard are primarily training devices, or act as a means of examining human factors involved in a conflict situation.

The other purpose of war games, and the one that this paper will be concerned with, is the use of war games as an analytic tool, the results of which may be used to guide military planners. To qualify as a method of analysis, the gaming method must go beyond the education and enlightenment of those directly connected with the game model and it must produce results upon which future action can be based. Some analysis has been done in the past using war games, but the action taken has been limited to tactical changes where the game itself has

served as a focusing device to point out faults to be corrected in the field. The game results have seldom dictated major strategic upheavals. Today the war game is being called upon to perform a greater and more crucial service. From this type of analysis many decisions must be made, not solely restricted to tactics, but involving weapons systems procurement, the future of deterrent systems, employment of military resources on a world scale, and a host of problems whose solution may never be tested in the cold light of reality. Often no experience is available to corroborate analytic results obtained on these subjects.

Analytic war games can be devised in a great variety of forms. The simplest being the mere thinking out of a conflict situation by assigning moves to the enemy and determining counter moves. This primitive mental game has been formalized into games like chess. At the other extreme, large manual war games are conducted periodically in the form of fleet exercises with "friendly", but unpredictable, enemies. Although the primary purpose of these workouts is training, post-exercise analysis is getting increased attention.

While it is not imperative in this paper to distinguish between a machine-played game and a similiary game played by hand, the computerized game will be dealt with since it is becoming the foremost method of "playing" large scale war games. An important distinction to be made is that the analytic technique to be discussed consists of a complete model with all rules and decisions built-in, as opposed to manual war games where human decisions are injected during the play of the game and conflicts are often decided upon by umpires.

The type of war game that will be evaluated in this thesis is the "paper" game which consists of a mathematical model, and the play

of the game is performed entirely by computer. In the critique of war gaming to follow, the structure and components of computer simulated war games will be examined first, followed by some discussion of the overall objectives and advantages of this method of analysis.

CHAPTER II

INTERNAL STRUCTURE

Ask anyone to pass judgment on war game results and immediately he asks, "What are the assumptions of the game?" There seems to be more concern with what goes into simulation than into any other form of analysis. In this chapter, the contents of a war game will be explored with the hope of discovering the origin of this apprehension about assumptions and seeing to what degree they differ from the assumptions made in the solution of any problem containing undetermined quantities.

First of all, it should be noted that, in the short history of operations research of military matters, many results of reports and studies have been accepted as indisputable mathematical truth, and some fleet doctrines have been based on these results. If the mathematics could be verified, the assumptions often went unnoticed. With the advent of computer simulation, however, the results are being held provisional. It could be the physical form of the results which causes such reservations. The results come out neatly arranged and explicitly stated, yet one is forced to wonder how they were generated. No decisionmaker can accept results of this nature without some knowledge of their origin. Certainly a military strategist must be satisfied with the a priori assumptions of a war game before he can take action on the results. It may be a blessing that this type of analysis has directed attention to assumptions made in all types of analysis, whether the actual reckoning takes place within the computer or is delineated in pure, but unintelligible, mathematical symbols. It is becoming clear that the acceptability of results rests as much with

what is presupposed as with the rigor of the methods used.

Assumptions occur in many shapes and forms. The internal structure of the war game will now be examined to see where, and in what form, assumptions arise, and whether they are necessary or justified. Of special interest will be the observation of those assumptions which appear to be unique to the war gaming method.

1. <u>Mathematical approximations.</u>

In the writing of a war game, all phenomena involved must be reduced to mathematical form. In this reduction, approximations begin to appear. Radar and sonar coverage areas might be described as perfect circles. Navigation is often depicted with straight lines. Nuclear bursts are given perfect spherical form. Equations are formed from extensions of "best fit" curves to areas where no data are available. There is no end to the estimations which must be made when a physical situation is being pictured mathematically.

With the necessity of approximations assumed, the problem which presents itself to the analyst is the choice between an approximation consistent with the latest scientific information, possibly unmanageable, or a form more easily handled but amounting to a cruder approximation. This problem is not unique to simulation. However, simulation is an attempt to portray all the meaningful features of the real world whereas much strictly mathematical analysis deals with idealized cases and is satisfied with a specific maximization or minimization of functional relationships. Therefore, the burden seems to be on the war gamer to seek the most accurate approximation that he can formulate and program. The heart of war game theory is the presumption

that while the performance of the entire military complex is unknown, the performance of each element is known (8). If this were not the case the gaming method would not be feasible. To "know" in this context is to be able to describe the element mathematically as a numerical parameter or as the root of an equation.

The equations and parameters used are themselves approximations. They come from two sources: theoretical inquiries and empirical data. Hopefully, the two will support each other. Generally, the war game builder desires to describe an entire event, but information from the two sources covers only parts of the event. This is often the case when nuclear explosions are simulated. The theory of nuclear effects is incomplete and the data available to date relate to a few specific occurrences. Thus, if one is war gaming an ASW problem using nuclear depth bombs, he has to account for the effects of these weapons with very limited knowledge of their actual effects. Whether his approximation will adversely affect the results will depend largely upon the objective of the game. This relationship will be discussed later in the section on game details.

While the above approximation may be crucial, other approximations appear to be both harmless and extremely handy. For example, in many ASW problems a sonar search pattern is determined by using the sonar range as a radius to describe a circle about a transducer. Undoubtedly, the true search pattern is not a constant geometric shape, let alone circular, but varies continuously with ship motion, water temperature, etc. Unless it can be shown that the actual pattern is markedly different from the circular approximation, an attempt to

picture it more accurately would mean an increase in labor greatly out of proportion to the increase in accuracy.

The military war gamer must not only produce a mathematical approximation for each element of the game, but he must also have some feel for the sensitivity of each parameter in order to balance accuracy with ease of handling. On one hand, the data may be so sparse that he has no choice of degrees of accuracy and ease of handling is not a problem. In this case, however, the limitation on the simulation does not necessarily have to be a fatal flaw as long as those who aspire to make use of the results are made cognizant of it. The merits of the gaming technique should not rest on the fact that knowledge of the real world is incomplete, but rather on how well it uses this knowledge to produce meaningful results.

With an abundance of data, on the other hand, accuracy and ease of handling may both be affected by the limits of the computational methods. Even if some action can be described mathematically, its inclusion in the game may be prohibited by the capacity of the computer to handle many such extensive calculations and still satisfy the objective of the game in reasonable time and at reasonable costs.

When there is very little or no information available on a particular parameter, it is occasionally the practice to either assign such parameters arbitrary values or ignore them completely. This expedient usually breeds dark suspicious in the mind of the user. There is other recourse. It may transpire that someone with operational experience will be able to indicate whether the parameter in question will be crucial to the objective sought. If not, the para-

meter can be injected into the game and allowed to take on a wide range of values through different plays of the game. This, of course, is a lengthly procedure and may convert the simulation into a parameter sensitivity test. Such a test is not an unworthy use of the simulation method since information as to the criticality of a parameter may not only provide a spark to further analysis, but may also lead to examination of the associated element in the fleet.

These questions concerning the degree and desirability of mathematical approximation lead directly to the problem of how much detail should be included in the structure of the game.

2. Detail.

Accuracy of detail. The accuracy of detail pertains to the assignment of numbers to denote equipment performance or as part of the previously discussed mathematical approximations.

Since a physical situation is being approximated, the detail in the approximation cannot exceed the know detail of the real situation. Any attempt to represent a parameter with a number of six significant figures when the parameter is only known to three will introduce unnecessary error. A military conflict is simulated by delineating each component which is of known capability and allowing the components to interact in a perscribed manner. Errors introduced in the description of the components may very well become multiple errors as the interactions occur. It would follow then that if an element or component could be described adaquately by a single number or equation, it would be preferable to do so, rather than describe its sub-components in detail. Whether this is the better approach will depend on the purpose of the game.

The rule on accuracy seems to be: be as accurate as the current knowledge of the actual item will allow, provided the data can be mathematically described and programmed within the practical constraints of the simulation. No such rule exists when dealing with the amount of detail.

<u>Amount of detail</u>. Those engaged in building and using a war game must, of necessity, consider every aspect of the situation being simulated. Part of this consideration is to limit or extend the completeness of description of each event. The gamer is torn between two beliefs; that everything of significance must be included, and that a conglomeration of detail can cause the program to become unwieldly and increase the difficulty of having the game and its results understood and appreciated. The urge to program every conceivable detail is fostered by the apprehension that one cannot know the effect of an omitted detail. It seems that a detail included and found unnecessary, can be removed, but one left out may always provide grounds for declaring the game "unrealistic". Elaboration, therefore, is sometimes sought in order to claim verisimilitude.

While there is presure for detail, there are strong reasons for limiting it. The most obvious reason is that the work involved in formulating the action mathematically and then programming it seems to increase in a non-linear fashion as more sub-systems are described. This practical consideration places an upper limit on the minutiae, but it does not provide a working rule with which to sift out the essentials.

How then, in a given game, can the amount of detail be decided

upon? In general, the answer to this question can be found only by considering the objective of the game. In any game, the effects of certain systems are to be studied while the rest of the game provides the proper environment in which to evalulate these systems. The "atmosphere" should be created with a minimum of detail. If the object of the game is to examine specific weapons or tactics, one is not only concerned with the effects of these systems but also with the causes of their effects. Therefore, the critical element must contain enough detail to ascertain, if possible, where weaknessess exist and what components are most sensitive. On the contrary, elements of the simulation which are merely effects should be programmed as effects, not only to save labor, but to insure that they are programmed as they are experienced and not generated erroneously by a complicated routine containing many approximations.

Suppose, for example, one is interested in testing the effectiveness of shipboard missiles against attacking aircraft. It would be appropriate to characterize the missile system in enough detail to check all phases of its usage; firing, flight path, acquisition, kill, etc. Even when this is done there will always be some doubt of the completeness. Should the weather be considered? How much should the aircraft be allowed to maneuver? These questions, and many others, appear to be answerable only with the advice and consent of the ultimate user of the game, who presumably has operational experience in this area. It may, however, be possible for the game itself to determine the significance of some of these factors.

On the other hand, a percentage of the attacking aircraft may

splashed for reasons other than missile hits. They may go down before contact; they may get lost; they may be brought down by surface anti-aircraft fire of picket ships, or intercepted and destroyed by combat air patrols. If we are interested only in shipboard missile effectiveness, these other losses could just as well be lumped into one attrition factor or "effect" and programmed as a single degradation of the attacking force due to causes other than missiles. Where the desire is to account for effects alone, it is often more accurate to program the total and final effect *per se* rather than construct it from component causes which may be less known. At the same time, it should be noted that if the objective of the game is to study the effectiveness of the entire task force against attack, these other causes of "lost" aircraft must be described in detail.

Consider the problem of determining ASW tactics against transiting submarines. One common measure of effectiveness is kills per transit. In arriving at a kill, many games are set up to include contact, classification, torpedo firing, chase, acquisition, and kill with a probability associated with each separate event. Is all this necessary? Presumably, all action takes place after contact. The number of kills may depend on a parameter attached to the torpedo or some other part of the weapon system whose fuction is determined probabilistically. Yet, if tactics are the prime concern, it may be sufficient to tabulate only the number of contacts. The forces are usually arranged with regard to contacting the enemy and therefore the number of contacts per transit may prove a more useful measure of effectiveness, while at the same time the calculations, and resulting errors, of

torpedo motion could be avoided. The inclusion of this detail may even have the effect of hiding the sought after data.

There exist sound reasons for the inclusion of a large amount of detailed descriptions in any simulation, but the gamer and the user must constantly compare the necessity of this detail with the objective of the game in order to hold it to a minimum.

3. <u>Nonquantifiable assumptions</u>.

The third consideration in this area is with assumptions which may be called nonquantifiable. It is in this area where gaming encounters some unique difficulties.

As a war game is developed, all factors that arise in the field are examined and some judgment has to be made as to whether the factor is to be included, and in what form. The factors which are measurable and can be determined empirically have been discussed above. These include approximations, descriptions, details, and, in general, the physical characteristics of the system under scrutiny.

Some factors cannot be quantified, yet are of extreme importance in simulation and must therefore be taken into account when the game is initially constructed. For the most part, the nonquantifiable performance involves the unpredictability of human behavior or the unknown forces of nature. Almost every event of a war game is predicated on the decision of someone in a position to initiate the action, even though the event description consists only of the physical action or just the effects of the action. Inherent in this procedure are assumptions about human behavior, and such assumptions should always be made with care. These assumptions are often called "hidden"

assumptions since they are seldom stated explicitly in the game description. Virtually every element introduced in to the game carries with it an implicit or hidden assumption. Three broad areas of implied assumptions are: enemy action and purposes, friendly forces performance, and the natural environment.

Enemy action. In a computer simulated war game the enemy units must be given some courses of action or, in a sense, animated. The assignment of courses of action amounts to a major assumption, and care must be taken to avoid setting up a "paper tiger" to be destroyed by the proposed forces of the war game user. The enemy conduct may be predetermined or arrived at randomly, but it should be as realistic as the game demands.

For example, in a submarine transit problem, the enemy submarine must be assigned some track in order to present a threat. In some simulations, an initial position is chosen randomly and the submarine is dead reckoned in a straight path. Is this realistic? Probably not, but is the assumption of a straight track detremental to the value of the analysis? Here too, one must look to the objective of the game for a criterion. It may be preferable to use a series of random positions. In either case, some assumed motion is essential. The above mentioned assumptions cannot be side-stepped and it is imperative that the user understand and accept them if he hopes to profit from the results.

Friendly forces. Similiar assumptions appear in the account of one's own forces, even if it only means assuming that they will carry on in accordance with past performance. More often than not, future

performance must be assumed. Like mathematical approximations, the aim is to make assumptions as close to the real performance as feasible. Often "a figure of merit" is assigned to the performance of a piece of equipment in both actual and simulated usage of the gear. This represents a more precise, but still only partially correct, assumption of how the given equipment will perform when needed.

Frequently in war gaming, assumptions have to be made concerning communications; an integral part of any military engagement. Even if communications are not mentioned, the implication may be of one hundred per cent reliability, which is a supposition worthy of careful study. It may prove to be justified or even immaterial as regards the purpose of the simulation, but it should not be overlooked or ignored.

Natural environment. The third realm of supposition mentioned above is the portrayal of the natural world. "Assume a situation" implies a myriad of "supposes" and they all must be accounted for in the final formulation of the problem. Accounting for such items does not necessarily mean inclusion, but rather inclusion or thoughtful rejection.

For instance, the underwater environment is of grave concern to ASW forces and contributes to the headaches of those attempting to effectively simulate the action against an evading submarine. The effect of water temperature on the speed of sound alone causes grey hairs amoung ASW tacticians, although it may be ignored by some war gamers. The ignoring of this factor is itself an assumption that the true tactical results can be obtained without considering explicitly the effect of changing water temperature on a sonar search pattern

This assumption may be valid in some individual war games, but the user should be aware that it exists.

These are some examples of the numerous presumptions and conjectures which are part of any description of a real world situation, especially a world as dynamic and complex as that of modern military conflict. Since a perfect replica of the conflict situation is impossible to attain, one must settle for an imperfect model built, not only on known facts and sound theory, but also on assumptions and personal judgments. The user of the war game cannot ask for absolute reality, but he can ask that models which are far removed from reality be explained and warranted before the results can be accepted as reliable and useful data.

In closing, a distinction should be made between internal approximations, details, and assumptions, and inputs to the game itself. An input parameter may be a fact, an approximation, a figure of merit, or a plain guess, but it is determined by the user to describe an element or event as he wishes it to be described. The problems explored in this chapter deal with the internal structure of the game over which the game user very often has little control. It is upon these features of internal logic that the decline or rise of war gaming as an analytic device rests.

Most of the internal description of factors regarding the fickle ways of nature and fuzzy human behavior are handled mathematically with the use of probability distributions and Monte Carlo techniques. These methods will be discussed in the next chapter.

CHAPTER III

SIMULATED DECISIONS

Thoughout the long history of war gaming, the practitioner has been consistently concerned with one important process; the decision process. The game in its primitive form was used to "try out" tactical choices against supposed enemy action. The enemy action could be entirely predetermined or improvised as the game progressed. Likewise the decisions by the game player could be made as the situation evolved, in which case the game provided decision making experience as well as analysis. An entire series of possible decisions could also be laid out before the game, thus establishing selection rules for action when the facts called for a tactical decision. This latter type of setup was, in reality, the testing of an entire war plan for a strategic situation or the testing of a battle plan for a tactical situation. The decision rules were conditional and formed a policy for action. The purpose of the game was very often to test the effectiveness of the military policy proposed.

In modern war gaming, these two types of decision methods are similiarly applied. The first method, utilizing human decisions during the play of the game, is the prominent feature of the present manual war games and tactical training devices. The second method, in which decision rules are preprogrammed, forms the basis of current computer simulated war games. Present war gaming analysis is not restricted to the investigation of policy effectiveness alone, but is used to examine such problem areas as determination of changing force levels, need and utilization of improved weapon systems, and

many other factors bearing on the state of military warfare. However, the essence of simulation analysis is contained in its decision making process which allows for the virtual carrying out of a complex military interaction and the systematic following of it to its completion.

In a strict sense, a decision is a conscious choice of a course of action from alternative courses of action. The war gamer is looking at the consequences which come to pass as a result of these choices made by different units in the course of battle. In addition to the above sense, the term "decision" will be used in this paper to signify the outcome of an engagement of forces, as in the case of a prize fight "decision" or the downing of an aircraft. One appeal of war gaming as a method of analysis lies in the fact that each event and interplay of events is "decided upon", or adjudicated, in the play of the game as it would, or course, in the actual conflict.

The simulated war game has the capability of letting the various forces interact, or generating reactions, and of deciding conflicts without definite knowledge of the tactical cross products. In other words, it provides a "try it and see" technique. For purposes of analysis, the ingredients of the decisionmaking process need not be known since one is interested in the <u>effects</u> of the decisions on the tactical situation. Essentially, there are two kinds of decision processes in a simulation: the predetermined decision and the random choice event.

1. <u>Predetermined decisions.</u>

Very often in mathematical analysis the outcome of an interaction is predetermined. Since the outcome is forced by the events of the

game, there is no "choice" or uncertainty connected with the result.

A familiar example is a description of radar coverage areas as circles and any intersection of this circle by a represented flight path of a hostile aircraft is considered to be a detection which automatically initiates a tracking event. The decision to be made here is when detection occurs and this has been determined in the programming of the game. The play of the game consists of consulting certain formulae or equations to check for geometric intersection. The procedure, in effect, represents a "decision" of nature that detection is immediate. A human decision could be simulated in this case if the program were to track and interecept the invader, since, in reality, a human decision is required to initiate such action. Nevertheless, the decision to track all detected aircraft has been made by the developer of the game, and is carried out automatically when certain conditions are fulfilled.

Decisions which are predetermined to produce a definite response to a definite situation have an analog in actual military policy. Standard operating procedures are ideally designed to insure a uniform and supposedly optimal response to certain tactical occurrences.[1] In such cases, the decision is predetermined when and if the event occurs in a certain manner.

In like manner, the effects of nature may be predetermined with the utilization of equations based on experience and scientific investigation of the phenomenon involved. In the simulation of a

[1]Examples: "track all unidentified blips"; "if communications are lost for five seconds on final, climb to two thousand feet and hold"; "do not fire until you see the whites of their eyes".

nuclear depth bomb burst, damage may be assessed in accordance with a previously discovered rule, usually based on an estimated lethal radius and the distance from target. While this type of determination may not be a perfect replica of the natural event, it will, if based on reasonable accurate data, describe the event in a useful way. By "deciding" the outcome of many such events, the game will hopefully yield results similiar to the actual conflict results while, at the same time, creating a history of the battle which can be of immense analytic value.

It can be seen, that if the entire conflict were carried out using formulae and equations which were completely deterministic and allowed only this type of decision, the "game" would be only an analytic solution utilizing the computer as a bookkeeping device. There would be no choice or chance inherent in the interaction and the simulation, as such, could not be properly labeled a war game.

2. Random decisions.

It is obvious that the real world does indeed contain a large measure of uncertainty especially when considering a clash between two strong forces, and this is appropriately carried over into a realistic simulation of the analytic version of the opposition of these forces.

Before looking at the method of injecting chance into a problem, it may be informative to see why it is desirable to do so. Consider, once again, the aircraft entering the radar search circle. In the deterministic case contact is made if the two lines intersect, or more explicitly, if the two equations have a common solution. Is actual radar contact this certain? Suppose it was a submarine entering a

sonar range circle, would contact be 100 per cent certain? In either case the answer would most likely be in the negative. Experience shows that each type of search equipment has some probability of contacting a target at certain ranges. This probability may be hard to pinpoint and will usually be estimated from test data or previous analysis. In war game analysis it is generally preferable to reflect this reduced reliability than to assume perfect performance.

In the examples mentioned earlier when predetermined human decisions were simulated, one would naturally contend that standard policy is not always carried out, and that responses to tactical confrontations are not, in fact, uniform and predicatable. Some mechanism to allow for human choice and human error seems appropriate when describing the real world. The results of human decisions will always be uncertain and one aim of war game analysis is to facilitate the improvement to tactics, policy, weapons, and military planning in general to cope with this uncertainty.

Other human decisions of great importance are those whose effects manifest the action of the enemy. It may be beneficial in some analysis to restrict the enemy to a definite course of action, but more often than not, especially in war gaming, the interesting results are obtained against an unpredictable enemy. His freedom of choice is discernible when his motion is described in a probabilistic fashion.

The Monte Carlo technique. The vehicle for injecting choice or randomness into a war game or any simulation is known as the Monte Carlo method (24). Probably the oldest and simplest use of this method in military affairs consists of throwing the dice. This device

is used today in manual war games and some fleet exercises. A torpedo, for example, is launched against a submarine, either at sea or in a "paper" exercise. It is desirable to make some assessment of possible kill or damage. Aside from using real war head, a dubious peacetime practice, this determination of damage must be arrived at from the known capabilities of the weapon and the armament of the submarine. If the role of the dice turns out to be a previously specified value or greater, a kill might be assessed. If not, the torpedo is assumed to have missed or, perhaps, inflicted minor damage. From the stand-point of getting on with the exercise, this constitutes a "decision" as to the outcome of the attack. However, for analytic purposes, little information is gained unless the set of kill "rolls" corresponds closely to the actual kill probability.

The Monte Carlo method then is nothing more that sampling from a probability distribution, which, it will be seen, does not have to be known explicitly.

In computer simulations, the throw of the dice is replaced by generation of a random number. In a simple example, where the probability of success is 60 per cent, a number is generated in a programmed subroutine so that it lies randomly between 1 and 100, then the generated number is compared with 60 to determine success or failure. There are many elaborate subroutines to transform the random numbers into an appropriate sample from any one of a number of common frequency distributions such that generation of random numbers is analogous to sampling of a given population (10).

It should be noticed that when dealing with a given probability

distribution, one is sampling from an artificial population which has a distinctive mean and variance already known.

The true usefulness of the Monte Carlo technique is manifest when the analyst is faced with the situation in which, not one, but large a number of interactions are to occur. A brief description of a familiar tactical problem may illuminate the use and merit of the Monte Carlo technique.

Consider the contact, tracking, weapon launch, acquisition, and kill of a submarine by a surface destroyer. In any defined geometric configuration, it must be assumed that the probability of success of each of the five aforementioned events is determined as an input to the game. This minimum information is essential to the initiation of the Monte Carlo process. The final overall kill probability does not have to be known. Returning to the example, the game has progressed to the point where the submarine has entered the sonar range of the destroyer and has some probability of being detected; say 0.8. One could make a drawing from a box containing four white balls and one red ball and thereby "decide" whether detection takes place or not. As the submarine proceeds on course, determinations of this nature could be made at regular intervals, using different probabilities for different ranges. This procedure simulates tracking or possibly, lost contact. If contact is held long enough to justify an attack, another sample could be drawn from the "box" population corresponding to the probability of a successful weapon firing and the success or failure of the launch could be established. Once again, the geometry of the model takes over and the two tracks are extended to find the closest point of approach of the torpedo to the target. From here

the program goes to the probability distribution for acquisition, usually a function of range, and hence, if applicable, to the final determination of kill or miss from still another probability reflecting the lethal power of the warhead.

A computerized war game can carry out the above interplay for numerous forces on both sides. The Monte Carlo technique, by deciding each interaction uniquely as it occurs, from given independent probabilities, can lead to an end result through a large number of events and intervening actions. This result, average number of kills or average kill probability per transit, will approximate the mean of the kill probability distribution which was never uniquely determined.

It must be emphasized again that the single event probabilities must be introduced as inputs to the game, and that the Monte Carlo method of sampling is not a computational device for arriving at a definitive solution to the problem. The value of the results will depend upon the assumed initial probabilities.

The problem connected with any situation in which the individual elements are reasonably well known is to assess the results when all these elements are allowed to interact and intermingle. To try to locate and separate each cross product distinctly is an immense task and then each cross product must be related to still other combinations of actions, the net effect being almost impossible to follow. The Monte Carlo method offers a means of permitting each unit to carry on its purpose and to respond in a manner similiar to its natural function in its native environment, so that the total effect can be manifest without being formulated. To be sure, the method does not define a

solution, but only "keeps track" of interactions and "decides" con-
flicts, but in doing so it provides a history suitable for study and
analysis.

CHAPTER IV

RESULTS

The most perplexing and pressing problem facing a military planner who is dealing with war games is analysis of results. If the war game is to be a useful analytic tool the results must not only be consistent and believable, but they must also contain enough meaning and relevancy to be definite contribution to the decisionmaker.

Many words have been used to describe war game results; valid, invalid, true, useful, unrealistic, hogwash, etc. It must be admitted that the war gamer himself is usually most restrained in labeling his product. The attempt in this chapter will be to organize a few of these labels, so that the military reader may defend or attack such results on relevant grounds and so that he will have some idea of the worth of the data in his possession.

Before proceeding with analysis of results, one point should be raised at the outset. The purpose or objective of the simulation must be firmly understood before attempting to make sense of the results. This may seem obvious, but the easiest way to deceive oneself is to study war game results as independent data without knowing how or why they were generated. Results not directly related to the objective may be very enlightening. However, they are better considered as subjects of further analysis than as end products. It should be clear that only results which are direct offsprings of the explicitly stated objective of the game should be given major attention.

This chapter will be confined to looking at results from three aspects with the main aim being an attempt to aid the reader in making

better judgments as to the worth of war game results. The three aspects are: Stitistical Significance, Logical Validity, and Comparsion with experience and intuition.

1. Statistical significance.

Upon completion of a run of a war game, the computer spews forth a set of output data. One may well wonder why this cannot be treated as the unique solution to the problem as in the case of many other analytic studies. After all, one set of input parameters should yield one result. It will be recalled that one distinguishing feature of the war game is the employment of the Monte Carlo method in the decision making process. Using this method, there is no assurance that the result of one play of the game is a very likely outcome. If the game is run again with the same parameters, a new outcome may well appear and may vary considerably from the former one. This is not surprising when it is remembered that the outcome of the game is a member of a probability distribution composed from many probabilities and one play of the game is considered statistically as one drawing from a population of all possible outcomes of the game. What the analyst is seeking is some knowledge of the parameters which define this distribution of the outcome, namely, the mean and the variance. For example, if the outcome of the game is the number of bomber penetrations, one is not so much interested in individual plays as he is in the average number of penetrations over many plays of the game. The obvious question is how many.

By treating the results as samples from the population of possible outcomes, the problem becomes one of statistical sampling

theory. While there exists a great body of information on the subject, this paper will be concerned only with what careful statistical analysis can contribute to the comfort of the military planner confronted with a myriad of data generated by a war game. Some assurance is needed that the game has been played enough times to give the user a high degree of confidence that the results adaquately represent the true model output. In other words, he wants the answer to the above question of how many plays are needed.

The principle of statistical inference states that the parameters of the parent population can be inferred from a study of the sample distribution. The degree of confidence in these parameters will be determined by the sample size, which in war gaming means the number of plays of the game with one set of inputs. The statistician can arrive at a confidence interval about such a parameter which gets smaller as the sample size increases.

For example, in fifty tosses of a fair coin, the proportion of heads may vary from 0.4 to 0.6, but in 5,000 tosses the proportion of heads will seldom vary more than from 0.48 to 0.52 (27) One is more confident of the mean proportion of 0.5 with 5,000 tosses. In war gaming, one is usually interested in some mean number of kills, or contacts, or penetrations, and the statistician might examine the results and announce that the mean number is 27 with a 95% confidence interval from 24 to 30. This means that there is an objective probability of 0.95 that the mean will lie within this interval. An increase in sample size may reduce this interval or produce a similiar interval with 99% confidence. Such an improvement may be

very costly in additional plays required. The war game user has to make a judgment about the size of the sample desired. If the confidence interval is adaquate for his use, he would be well advised to limit the number of runs for at least two reasons. First, computer time is expensive, and secondly, the war gamer is usually desirous of making parametric changes to the inputs and then examining the new results. This requires multiple plays of the game for each change of inputs, each needing statistical vindication.

Other statistical methods can be of value in further analysis of the game results. A common practice in gaming analysis is to vary one important parameter and note the effect, if any, on the output. Suppose increasing sonar ranges were arbitrarily assigned to a surface unit in an ASW exercise, and a linear increase in contacts per transit was experienced. The assumption of linearity can be verified by examination of the data using statistical methods of correlation and regression analysis (6).

What does the statistical significance of results mean to the beneficiary of war game results? It tells him, primarily, when he has played the game a sufficient number of times to have a high degree of confidence that the mean and variance obtained is the true population parameter of the output. This confidence should not be unrestrained since the statistical methods deal only with the numbers produced by the model as it stands and the "population" of plays pertains to the model and not necessarily to the real conflict being simulated. The statistician is only assuring him that the number that he is looking at is representative of the average outcome of the model and not a fortuitous case where the internal decision

mechanisms have produced an unlikely result. Other mathematical treatments of the results, i.e., graphical analysis, regression analysis, should be viewed in the same light, as truisms about the model, not about what is being modeled.

Much information about the nature of outputs and the relationships between inputs and outputs can be extracted from this type of analysis. However, the burden is still on the war gamer to relate this information to the actual tactical or strategic situation. He must ask not only if the results are valid in the model, but do they correspond to their image in reality.

2. Logical validity.

In formal logic, a conclusion is considered valid if it is arrived at by rules of reasoning of a definite and consistent form. Rules governing the subject and predicate of the major and minor premise will determine the validity of the conclusion. Once the validity of the conclusion is established, the truth of it will depend on the truth of the premises. If the conclusion is valid, meaning it follows logically from the premises, then one can establish the truth of it if he can establish the truth of the premises. An invalid conclusion, since it does not follow logically from the premises cannot be labeled true or false from knowledge of the truth of the premises. A conclusion may, of course, be invalid, but true. The rules of formal or mathematical logic can become very involved, but the underlying principle is to construct the logic in such a way that agreement is reached on what conclusions can be drawn from known facts and which conclusions are supported by the facts and which are not.

War game results may be looked at as conclusions in the sense that they follow from the internal logic of the game. The question facing the analyst is whether they follow by the rules acceptable to him and does the playing of the game always take the course intended by the user. In any mathematical study, the one who must act on the results must be satisfied that the outcome follows from the input according to the laws of logic, or laws of set theory, or of trigonometry, or whatever disclipine is being used. Take, for example, the elementary trigonometric equation for finding the length of the third side of a triangle, when two sides and the included angle are given (The Law of Cosines). After seeing the "law" developed from basic geometric and trigonometric postulates, and being satisfied that the logic is sound, the user will confidently insert inputs (the two given sides and angle) and find the value of the third side. To him, the result is valid, and true if the three original inputs were true to whatever they represented.

Logical validity of war game results is essentially the same concept, but much more difficult to achieve in practice. If one could trace through the entire program to ascertain the rules used in the determination of the outcome, then he could be assured of the validity of the results. He might like to know whether the equations reflect logically consistencies, like, to take a simple case, are radar contacts adjudged only within contact range of the piece of radar?

The value placed on game results by the military planner will vary directly with his confidence in the validity of the process. Since he supplies the inputs and is responsible for their "truth",

he needs only the assurance that the often elaborate and complex game logic is giving him a logical flow from input to output. This assurance is in addition to an awareness of the approximations and assumptions mentioned in chapter two. Except in the case where the game user and the builder are the same person, it will be next to impossible for the user to trace through the entire game to satisfy himself with the logical consistency of the structure. To some degree, he must rely on the skill and integrity of the individual who built the game.

This confidence may be attained by a fully documented game, or, more easily perhaps, by a close and informative partnership between the user and the builder throughout the development of the game. This partnership is difficult to attain at present since many war games are being built primarily by civilian analysts, sometimes working closely with the military, and sometimes working in an academic or non-military atmosphere.[1] Some familiarity with gaming techniques by the military officer is essential, and a working relationship of the military with the civilian analyst would be very beneficial.

The builder of the game is usually convinced of the logical and mathematical consistency of the system, but he must transmit this conviction to the military officer who must act on the results. In doing so by the method proposed above, the war gaming technique may serve as an agent in increasing the rapport between the civilian analyst and the military tactician.

[1]The degree of association with the military varies. This work is being done in many places; The Applied Physics Laboratory, The Rand Corporation, Stanford Research Institute, Systems Development Corporation, etc.

3. <u>Comparsion with experience and intuition.</u>

Another definition of validity specifies that statements or conclusions are valid if they can be supported by facts or empirical evidence. It is this test of the war game results which is most elusive and controversial. It is comforting to be confident of the logical structure of the model, and to know that the results are statistically significant, but given such a case, the analyst must now consider how much can be inferred about the real situation from the use of the model. Building an accurate and logical model clears the first hurdle, but establishing the relevance of the model is the crucial hurdle to cross. Unfortunately, there is no sure way to arrive at the realization that a model of a military conflict is relevant and, undoubtedly, unanimity of opinion will never transpire.

The model gets its meaning from reality, and the usefulness of a war game is measured by the quality of the knowledge which can be inferred about the real world by playing the game. The problem is one of properly making inferences from the simulated engagement. This translation of numerical results from an artificial situation to useful facts about reality is the ultimate responsibility of the military decisionmaker.

Two somewhat formal tests of logical validity and statistical significance have been suggested to tie input values to results. The third test of tying the game results to the real world by comparsion with experience and intuition is by nature less formal and requires continuous study, reappraisals, and subjective judgments, together with whatever data can be obtained from similiar fleet exercises.

Some examples may illuminate the nature and scope of decisions which may be called for when determining the usefulness of war game results. Suppose a war game is devised to simulate a hunter-killer team stationed in some defined area to prevent transit of enemy submarines. All units have been programmed as having capabilities which they presently enjoy, many of which will, of necessity, be probabilistic in form. The object of the game is to evaluate current tactics against this threat. The military planner is satisfied with the structure of the game, has supplied the input parameters, and has played the game a sufficient number of times to arrive at statistically significant results. Upon examining the results, he discovers that one type of unit, say for example the ASW helicopter, is very seldom involved with a kill, and almost never credited with an initial contact. Does one conclude that the helicopter is really not essential to the hunter-killer team and should be removed. If not, where do you look to explain the outcome which may be in disagreement with the outcome of similiar exercises run at sea.

Consider another submarine transit problem, this time using an SSK barrier. Once again, the barrier is set up to prevent enemy submarine transit through a specified area. The game is run using inputs as realistic as available, and the results show on the average 19 kills per 100 transit attempts over several plays of the game. A similiar fleet exercise is performed with results that 8 out of 10 submarines are killed. Here again, there may be a temptation to declare the model useless, since after all, the criterion for a good model is the predictive quality. Here an average of 0.19 kills per transit is predicted and actually 0.8 kills per transit occur.

These are but examples which point out possible conflicts which may arise when war game results are compared with experience and intuition. While there is no pat procedure to resolve these dilemmas, some guidelines can be listed to ease the burden of the decisionmaker faced with the task of making the best use of all sources of information available. They should be applied whether the game results are appealing or disconcerting.

Do not try to compare two different things. A model is not the real thing and was never intended to be even though it may reveal truth about the real world. Model results, looked at in absolute terms, are different in nature than live results, and comparsions of the two are difficult. The environment of the fleet exercise will probably be different from that simulated, and more important, the rules of assessing damage or kill are often not the same.

Look for relative improvement. The problem of comparing two types of results can be avoided by making comparsions within the game itself. If the purpose of the game in the second example is to evaluate tactics, game results should be compared with other results from the same model, but produced using different tactics. Here a marked increase in the number of kills or contacts, using the same input capabilities, may indicate a superior tactic. If a fleet exercise demonstrates the same increase with the new tactic, some good has been realized, regardless of the absolute number of kills or contacts by each method. An improvement in the game could lead to an improvement at sea even though the numerical results in each approach vary considerably.

Reexamine inputs first. When attempting to resolve discrepancies, reexamine input parameters first rather than tinker with the basic logic of the game. One of the useful analytic purposes served by fleet exercises is to shed some light on the performance characteristics of the various units. These performance characteristics are important inputs to the game, and erroneous ones may lead to strange results. As the game is continually adjusted to better reflect reality, the major adjustments will be to update the effectiveness parameters of the weapon systems described. In the first example, fleet experience may show that the helicopter has a much higher effective sonar range than was supposed in the model and hence, a greater contact probability. In which case, a correction in the model may produce results demonstrating the usefulness of the helicopter in the hunter-killer team. If not, the simulation may point the way to further critical analysis of the composition of the team.

Changes in the internal logic should follow only from a new and genuine understanding of the essence of the physical world which is being pictured. This will be more important in future games where no operational data is available for comparsion and the best one can do is to stabilize the model and vary the inputs.

Do not judge the game by the results alone. When the results come out in close agreement with preconceived views of the user, he may be tempted to consider the game valid, realistic, and even extremely astute. Likewise, results which contradict a pet theory are in danger of being branded useless and subsequently abandoned. On the contrary, the model should be evaluated by itself and not on the believability

of the results. As in the logical syllogism, one strives to construct a system which will produce valid conclusions, the truth of which will depend on the establishment of the truth of the premises. If validity of results, in a logical sense, can be obtained, at least with resonable assurance, then there will exist a connection between inputs and results that will make it easier to examine both. The model should be judged on its internal merit and the results should be judged only in light of the assummed inputs.

CHAPTER V

OBJECTIVES

Having reviewed the more important features of modern computer simulated war games, the remainder of this thesis will be addressed to the problem of the usage of gaming techniques to further military objectives. The present chapter will be concerned with objectives to be sought by the employment of the war game.

The military officer is continuously aware of the necessity of making the most efficient use of his resources in hand, of planning for new weapon systems, and of devising means of evaluating the new systems as they evolve. The theoretical side of this day-to-day appraisal is in the domain of operations analysis, and the objectives of war gaming do not differ appreciably from the routine objectives of operations analysis. The simulated war game is another tool of analysis which is still developing, and, like all new methods, can be of great value when used effectively and applied to problems which are amenable to this type of discipline. While discussing war game objectives, it may be observed that the classical purposes of war gaming and the post World War II purposes of operations analysis blend together in analytic war gaming and could bring to military decisionmakers a new appreciation of each method.

It has been emphasized throughout this paper that the objective of the game must be understood by the user (and, of course, the builder) in order to appreciate and, perhaps, tolerate the assumption on one end and the results on the other. This chapter will outline some of the feasible objectives of simulated war games and, where appropriate, point out their influence on internal structure.

1. Testing of war plans

The testing of war plans has been one of the historic uses of the war game. The idea was to devise a complete plan of attack to acheive some desired military end, and then to "play it" against supposed enemy responses, while taking into account, if possible, chance happenings which occur in any conflict situation. Weak points in the plan were corrected as they became apparent, and often, as a side product, insight was gained into a new tactical approach. The war game offered an opportunity to "try out" proposed plans prior to the time when they must be used for "keeps". The evolution of military tactics parallels, in some ways, the development of philosophy, in that heavy reliance was placed on the accumulated wisdom of the past and the insight of a few geniuses who crystallized concepts into workable rules. There was no method, outside of war gaming, to continuously evaluate and revise tactics in times of peace. The analytic war game, as a tester of plans, continues to assist in this area.

The modern computer simulated war game can and does serve this classical purpose; namely, the evaluation of various tactical proposals for handling and array of threatening situations. With this objective in mind, the game should be built with a serious intent of describing the military capabilities, enemy and friendly, as accurately as they are known to date. When the stated purpose is such a general evaluation, the assumptions, approximations, and internal structure must be geared to serve this purpose. This requires a true reflection of the real situation if comparsion of plans is to be meaningful. It can be seen that by taking as one's objective the determination of the best master

plan, the game must be made not only large, but accurate in essential detail. This requirement for accuracy of description of an entire modern war plan means that this objective can be achieved only with a great expenditure of time and effort, even with the aid of high speed computers. It may be advisable to seek a smaller objective on some occasions to avoid having to describe too large a conflict in minute detail.

2. Effectiveness of tactics.

The difficultly mentioned above can be reduced somewhat by considering only subelements of the overall strategic picture, thereby concentrating on local, relatively independent, tactical situations resulting from threats less than world wide. In this way, the war gamer can ignore or hold static many aspects of the environmental backdrop against which the engagement is played and thus reduce the detail required and make assumptions less demanding in verisimilitude.

Consider, for example, the defense of a mercantile convoy against hostile submarines. It may be the case that only two methods of defense are proposed: excort destroyers, together with ASW helicopters placed aboard the merchant ships, or a supporting hunter-killer team steaming in the vicinity of the convoy. The objective is to compare the effectiveness of the two teams against the same threat. This can be simulated with less detail than one would suppose at first glance. The convoy, in each case, can be programmed as a unit with little detail other than course, speed, and limited maneuvering ability. The enemy action can consist of attacking submarines of given capabilities, but the attention to detail in describing these capabilities can be relaxed as long as the same threat is presented to each proposed team. The description

of the enemy threat must be reasonably accurate, but the important thing is to make it similiar for each evaluation. For this limited objective, the environment can be assumed to be mid-ocean, removing the need for considerable geographic detail. If, on the other hand, the convoy problem was to be part of a test of a general war plan, it would most likely have to be programmed from start to finish in accurate detail. With a less general objective, the labor of building the model may be reduced considerably more than the corresponding loss in generality.

A point can be made here concerning the relationship between objectives and results. In the case of the limited objective, the game may "find" one method of convoy defense more effective tactically than the other against a given threat, but this does not imply that it should necessarily be chosen. The objective was to determine tactical superiority, while other considerations such as cost, maintenance, need for defense, probability of threat, etc., remain for further analysis. The overall war plan, if it could be modeled, might try to cover these items, but it should be remembered that the war game may accomplish its objective and still not answer all the pertinent questions on the subject.

3. Development of new tactics.

While discovery of new tactics is often a happy outcome of analysis designed to examine current tactics, it can also be a proper objective itself. As a matter of fact, the creation of new tactics to meet the rapidly changing threats of the cold war is a paramount importance in modern military planing.

Original tactics very often come about as a result of some mutation or reordering of current tactics as they are carried out in the battle. The experience gained from employing faulty maneuvers in the field will

be wisely used to contribute to different and better tactics in the future. This experience, combined with professional wisdom and insight, has been the main ingredient of new tactical theory.

The war gaming method, when given possibilities of multitudinous plays of a single battle by the computer, can investigate many combinations of available tactical forces to screen for a better approach to the problem. One no longer has to rely on happenstance combinations which arise in battle to see fortunate tactical employments. Likewise, proposed tactical innovations by military theorists can be evaluated in a simulated field environment in the same manner as current tactics, and the world does not have to wait for war to test the feasibility of new and revolutionary approaches to a conflict situation.

4. Determination of future needs.

The post World War II philosophy in national defense is based not only on having sufficient forces in being to cope with any threat, but also to be continuously developing new weapons and tactics to defend against all conceiveable weapon systems which the enemy has prospects of possessing.

In this regard, it is a logical objective of war gaming analysis to aid in this critical determination of future needs. In a given war game, the gamer has the privilege of setting forth the enemy capabilities, against which he will attack or defend. It is possible to increase the enemy capability by simply improving the input parameters which describe his action. The game is then run using existing talents of one's own fleet to discover how bad things will be and what units are going to particularly vulnerable. By then making incremental parameter changes to correspond to improvements in the fleet capabilities, another deter-

mination can be made as to the degree of improvement necessary to meet future threats.

It is often easy to see intuitively just where one's own fleet will suffer a disadvantage if the enemy inherits improved capabilities, but the degree or quantitative measure of self improvement needed and the exact nature of the weapon to encompass this improvement are not simply visualized.

5. Correlation between units.

The Navy is in possession of many different, sometimes conflicting, fleet units with which to do the job of controlling the seas. In ASW alone, there are three types of fixed wing aircraft, helicopters, destroyers, submarines, and numerous other systems with overlapping capabilities of detecting, tracking and killing enemy submarines. One of the challanges of naval leadership is to mold these diverse units into an efficient and mutually complementary team having the highest probability of accomplishing the mission. This problem is no different in concept than the ancient problem of deploying the cavalry, infantry, and artillery is such a way so as to achieve the maximum coordination and destructive power.

Modern tactical theory is often blocked because of the inability to identify and quantify the effect of one unit on the others when they are supposedly working toward the same end. There exists, whether it is explicitly stated or not, mutual interference, not all of which is involuntary. One way to attack this problem is to physically try the various feasible combinations enough times to appraise the different performance. For exampl , can destroyers track and attack a submarine

better in conjunction with patrol aircraft, helicopters, or alone? There is no shortage of opinions on this question, but it is difficult to get sufficient data from at-sea trials to measure the correlation between units, mainly because each trial is different and comparsions lose their meaning.

This type of comparsion is not impractical in computer war game analysis, where the ease of repeating plays makes the determination of this correlation an attainable and worthwhile objective. With this modern analytic tool, it is possible to arrive at a quantative measure of the interaction among units comprising a large military command.

6. Other objectives.

The objectives listed in this section are typical of the ones sought in current war gaming and, for that matter, are similiar to the objectives of all forms of analysis contributing to military planning. Those mentioned are ones particularly suited to war game analysis, and many combinations of these objectives are found in current military models.

There are many variations of the above purposes. To suggest a few: a war plan may be a defense plan, i.e. the establishment of the SAGE system or an equivalent system; future needs may be logistic rather than tactical as in a simulation analysis of the sea lift or air lift capability. Finally, in the area of tactics and correlation effects, the number of possible objectives to be pursued are increasing faster with each new complexity in modern warfare.

CHAPTER VI

MILITARY PROBLEMS SUITABLE TO SIMULATION

Very often in military affairs today, when the decisionmaker is faced with a threat which can be met with a variety of means at his disposal, he will look to the war game for a clarification or ultimate solution of the problem. What is there about war game analysis that makes it a wise choice in any given problem? In this chapter, the conditions germane to a problem which make it amenable to war game analysis will be discussed, with the purpose of giving the decisionmaker a better base on which to choose the means of analysis best suited to assist him. The format will be in the form of questions which should be asked and answered about each problem recommanded for solution by this method.

1. <u>Is the problem factorable?</u>

When experimenting in the physical sciences, the experimenter attempts to hold as many conditions as possible constant that are not subjects of his study. He is, in a sense, factoring out one characteristic of the physical situation and examining it independently. His success may depend on whether the observed effect is, in fact, independent of the environment.

A military exercise may be considered as an experiment; one in which there is very little control of the environment. In military analysis, however, it is desirable to look at one event or interaction at a time in an attempt to do a finite mathematical study and thereby find an optimal or effecient way in which the event should take place. Unfortunately, when dealing with a conflict situation in the real world,

governed by human action, it is very awkward to hold the environment constant to perform an analysis on one event. It is in this exigency, where factoring is impractical, that one might turn to the war game.

A factorable event can be removed from its environment and studied separately, whereas a nonfactorable event cannot(16). For example, the determination of the most effective size of a depth bomb may be made without considering the tactical atmosphere in which it is to be dropped. Once a criterion is decided upon (explosive power per pound, lethal radius, ship mounting convenience, etc.), reasonable results can be obtained. On the other hand, the problem of the most effective use of destroyers in a hunter-killer team cannot be abstracted from the context of the local tactical situation. The deployment of destroyers is not independent of such items as; the expected threat, aircraft availability, and the number and makeup of all the units in the area.

Thus, the ASW picture, on a tactical level, appears to be nonfactorable. Weapon capability, sonar and radar equipment, flight operations, and other facets of the problem may be improved independently, but when it comes to the best use of units or weapons in a unified plan, the analysis becomes muddled. The most efficient use of destroyers cannot be added to the most efficient use of helicopters in the same area with the hope of getting the most efficient combination. You may, in fact, get chaos. The helicopter search plan may be based on covering the maximum area of ocean space in some defined contact area, while the destroyers may be striving for containment. Both plans could be independently optimal, but the combined effort may be inefficient. The operation planner must now become concerned with a new situation and try to devine the correlation between the units.

Taking the group as a whole, i.e., nonfactored, seriously complicates the mathematical analysis, a situation which gets worse as more and more units arrive on the scene. Even to an experienced operational commander, the nonfactored tactical problem is a daily source of study and reappraisal.

From the analytic point of view, the nonfactored problem can be handled with more assurance by the war gaming method. In the game, as mentioned earlier, each unit and its effects are described independently and thrown together in an artificial world to examine their interations. The success of each combination against a given threat can be measured, and better combinations may become obvious when the data is assembled. The war game is doing, in effect, what cannot be done in the fleet; trying a large number of procedures and tactical configurations against similiar enemy actions.

2. Does a definite analytic solution exist?

Even when an event can be factored, it may be troublesome to analyze. One must choose a criterion by which to judge the results. When conducting ASW search, does one choose to maximize the ocean area covered in a given time, maximize the probability of containment, minimize the time to regain contact, or even minimize fuel consumption? For a definite mathematical analysis, some measure must be chosen, and it may not be adaquate when the entire situation is considered.

In war gaming, it is possible to hold the selection of this measure in abeyance, and examine the results as one would examine the results of an at-sea exercise. Some of the above measures may be within reasonable constraints already and not in need of specialized attention. The game may sufficiently illuminate the interactions involved to a point where

more meaningful factored analytic studies can be initiated.

In still other cases, the current mathematical methodology is not capable of dissecting certain tactical arrangements, or conceiveably, the circumstances have not been considered from a mathematical viewpoint. In either case, the war game may prove to be the only current approach, and its usefulness can be justified by the fact that it can produce results when they are needed and not forthcoming from other analytic methods in the forseeable future. When a definite analytic solution to a pressing problem is not likely, it is suggested that the war gaming technique be considered, provided it fits the needs of the problem. Nevertheless, as pointed out in chapter four, the results must meet certain standards to be given credence, and should not be clutched too lovingly simply because they are the only answers available.

3. Is fleet evaluation practical?

An analytic war game is by nature closely related to the manual or actual war game. They both seek the same objectives. The "paper" game is considered when it is impossible or impractical to make the desired evaluation in the fleet with actual combat units, and, quite reasonably, the real life game should be utilized when it is feasible. It may turn out that the most profitable arrangement will be fleet exercises run in conjunction with simultaneous simulation.

Computer war gaming is not an inexpensive passtime, and may not be justified if the same data can be obtained from fleet exercises which must be conducted anyway for training purposes. Better data processing in present operations could reduce the need for a considerable amount of artificial investigations. On the other hand, if the

cost of certain fleet exercises is prohibitive, the simulation method may become economically attractive.

4. Is the use of nuclear weapons anticipated?

This question is related directly to the previous one, but is asked separately because of the distinctive nature of evaluation of tactics involving nuclear weapons. These events cannot be properly evaluated at sea. This realization, coupled with the fact that many modern weapons have never been tested in their present form, forces the military analyst to rely heavily on scientific studies and simulation.

The Navy today is faced with a growing arsenal of weapons whose capabilities are not fully known. These weapons are becoming the core of our attack ensemble, and tactics must be designed to use them effectively. In a war game model, the nuclear effects can be given a wide range of values and various attack plans may be tested over this range. Hopefully, one plan will prove effective in that part of the range generally believed to be the true measure of the weapon capability. In this area, simulation may prove to be of exceptional value.

5. Does the proposed tactic depend on enemy action?

This question may seem trivial since the answer will be in the affirmative in every case. Nevertheless, a great bulk of the military analysis is done without considering specific enemy action, or else one definite action is assumed for a particular study. The response of the enemy is "factored out". This is often the case in studies of effectiveness of weapons, where the design of the weapon is such as to optimize certain fuctions (power vs. weight, convenience of delivery, etc.) without regard to the specific action of the enemy. If the weapon is properly delivered, the assumption is that enemy response is limited to dying gracefully.

In a large area of military studies, where tactical considerations involve tracking, searching, intercepting, and positioning units for weapon delivery, it may be deceiving to ignore, or arbitrarily assign, the enemy action.

Anti-submarine search plans, for example, are sometimes based on the principle of maximizing the amount of ocean searched in a given time assuming that the enemy is or will be in the area searched. This is often the most profitable approach when intelligence is sparse or completely lacking as to his approximate whereabouts. If, however, a datum had been established, a search based on ocean coverage, while maximizing the amount of high probability area searched, may not maximize the probability of detection. When such doubt arises, one tries the plan against some representative enemy evasive techniques to obtain a measure of success of the tactic. These tests may be run at sea or on paper. If the results are not satisfying, then the war gaming technique may be helpful. The search plan can be modeled, programmed, and tried against a great variety of individual submarine maneuvers. Used in this way, as a tester of tactical plans, the war game often proves to be an excellent complement to definitive studies.

Consider the case of air defense. Often a likely enemy air attack plan is suggested and the decisionmaker seeks a quantity of weapons and an arrangement of forces sufficient to meet and defeat this type of assault. After the study has provided for an optimal deployment of forces, it may come to pass that this "optimal" solution is very inefficient if the enemy chooses an unorthodox or unthoughtof method of attack. Rather than do a new study for each imaginable enemy action,

it may be desirable to program the defense and run simulated air attacks using all sorts of attack patterns.

The principle of allowing the enemy freedom of action when planning defense goes back to the first gaming, where the fundamental question was; "If he does this, then what action do we take?", and this question was asked throughout the play of the game. This principle is still applicable today, but is often overlooked in the age of ultimate weapons, where the emphasis is on total defense rather than defense against specific and probable enemy actions.

CHAPTER VII

ADVANTAGES AND DISADVANTAGES

While it is hoped that the reader will have, at this time, a general notion as to the advantages and pitfalls to be expected in the use of the war gaming technique, it seems appropriate to close this thesis with a specific delineation of the assets and liabilities that the practitioner can anticipate. It may transpire that, in quantity, the advantages outweigh the disadvantages when a list of each is composed. However, one should remember that with any technique in its early development the advantages tend to be alleged advantages, while the drawbacks are those which have actually been experienced. One serious drawback, discovered at the completion of an elaborate and costly war game can nullify a great deal of hard labor, and outweight many supposed advantages. A checklist, while not exhaustive, will be set forth here with the hope that by using it one may avoid such prospective disasters.

One judgment will never be entirely applicable to a specific problem considered for solution by war gaming, but it is envisioned that the description of general advantages and disadvantages of the method will assist the military planner in consigning his particular problem to the proper analytic technique.

There are many ways of attacking a problem, all of which may have mutual advantages. The concern here, however, will be with the particular features of the war game which sufficiently distinguish it as having unique advantages and disadvantages.

The citing of these selection criteria is meant to aid the mili-

itary decisionmaker in examining his analytic equipment. It is not proposed that the advantages be taken as overpowering reasons for pursuing this approach, or that the drawbacks be used to condemn the method, but that both be understood and appreciated when using the technique and acting on the results.

1. <u>Advantages</u>.

<u>A solution may be found where no other existed</u>. It cannot be denied that a system which produces an answer where none previously existed has an advantage over other systems trying to solve the same problem. Indeed, this has been one of the primary "selling points" of computer simulated war games. In the complex military world today, only a method which can cope with all the probabilistic events and unknown correlations can suitably describe the conflict in terms complete enough to yield valid results. The gaming technique is proposed to get a gross idea of the magnitude of an outcome when no concept of this outcome is in being. As they say in the trade, "to get a handle on the problem".

This advantage is becoming more and more dominant as an attempt is made to analyze the current defense posture in the atmosphere of possible nuclear exchange. With the offense and defense springing to action immediately and with one depending on the other, to an unknown degree, and both depending on the enemy approach and capability, the search for a "solution" to the global equation is tedious and unending. The war game is grasped in hopes of generating some initial idea of the quantity and quality of forces needed in both our offensive and defensive systems

The cynic may ask, "Is a gross (or wrong) answer better than no answer at all?" A good question if results obtained from poor war games are paraded as the only truth because they constitute the only existing solution to the problem. In this deceptive and dangerous situation total ignorance may be preferable, but a discerning decision-maker will avoid this trap by careful analysis of the game results as suggested in chapter four. Indeed, if the method is used in an area of analytic virginity, the results, while valuable, must be carefully validated least they be illegitimate.

Outcomes are determined, not described probabilisticly. Suppose a given weapon system has a 40% kill probability against a given threat. What does this mean? Is it a measure of past reliability, meaning that it killed 40% of the target attacked? Or is it a guess at the future reliability, based on the known performance of the components and an estimate of the enemy defense? Sometimes these probabilistic results leave the military planner in a quandary. How does he deploy a 40% effective system?

The war gaming method may remove this dilemma (while probably creating new ones) by making a determination of each event, using, most likely, the same known component capabilities. In the course of the battle, the game will undoubtedly show that the weapon system in question is approximately 40% effective, but by "playing out" each event, it may show where the kills occur and in what situations the system is useless. The history of the game will give the military decisionmaker a better picture of the part played by each weapon system than an analytic solution which states only the overall probability of success.

The game is "operational". This advantage of computer simulated war games is, quite naturally, derived from its similarity to actual or manual war games. In other words, it is an analytic or "paper" method which retains the feature of actual at-sea practice, the "try it and see" approach, an approach of proven military worth. This, of course, is the rationale behind classical war gaming and is mentioned here as a current advantage only in the extent that the current counterpart retains this characteristic.

The game aids in discovery of correlation amoung units. This trait was mentioned earlier as an objective of war gaming, but is listed as an advantage because it seems to be one of the aspects of the gaming technique most relevant and useful in modern military analysis. The methodical approach of operations research has been to break down a complex problem and examine each entity in its factored form. This procedure, labeled sub-optimization, tries to optimize each component and arrive at an optimal overall system.

This process, while productive, loses some of its power when unknown interactions occur in the overall problem, and the factored parts cannot be rejoined in a logical way with assurance of efficiency in the composition. Recall the example in chapter six in which the helicopter search plan was superimposed on the destroyer search plan with no guarantee of an efficient combined search plan.

The war gaming method will not define the correlation between units in these case. Such a definition would be an input to the game and the advantage of gaming would be lost if they could be defined. What the game will do, with its ability of repetition, is show which

combination displays a marginal increase in efficiency or probability of success. The best tactical combination of numerous units may be discovered by "trying" them all, even though the nature of the interaction leading to the best outcome is not discernible. The exact interdependence between units seeking the same objective may remain a mystery, but if the most effective method of deploying these units can be found, the mystery does not remain a stumbling block.

<u>Gaming analysis may be more realistic</u>. To suggest realism as an advantage to computer simulated war gaming may raise a guffaw from those exposed to the technique. More often than not, the prime condemning adjective applied to war games is "unrealistic". It is true that the simulation method does not purport to accurately photograph the real world. Since this is true of all modeling, to compare the realism of various models does not seem profitable. To claim realism as an advantage of war gaming it will have to be contrasted with the actual war game or fleet exercise method of obtaining information. Since all a priori military analysis is "unreal" in a strict sense, the question to be asked is which approach will lead to information most true to the real conflict.

It may be argued that the war gaming approach will never be more realistic than an actual fleet exercise of similiar content. Is this always true? It may be that anlytic war gaming will fit the criterion in some case. In many fleet "conflicts", the kill determination is made by the throw of the dice or is decided upon by an umpire. The umpire may be interested in extracting the most at-sea training from the exercise and the dice ratio may be designed to

favor a prolonged engagement for this reason. This procedure may be advantageous for training purposes, but leads to results which are unreliable for critical tactical analysis. For such cases, it can be more desirable to model the exercise and design the Monte Carlo techniques in such a way so as to reflect the unit capabilities as accurately as they are known. In effect, if the purposes of the fleet exercises (training and analysis) cannot be separated at sea, it may be more advantageous to resort to an analytic method which can make the separation and describe the interplay with a single purpose in mind.

<u>The game can be replayed</u>. The analytic war game, as has been suggested, lies somewhere between pure mathematical studies and operational games or exercises. Its replayability is an asset not generally enjoyed by the other two methods. In the field, it would be extremely enlightening to replay many of the actual operational encounters under the exact same conditions, thereby allowing for a meaningful comparsion between two different tactical approaches. This is seldom possible, and all too often there remains the suspicion that one system or tactic appears superior because of the fortunate conditions in which it performed.

The ability of replaying a situation is not absent from mathematical studies, which have some repetitive capabilities. It is often possible to change one parameter while holding the other inputs constant, and thus approximate a new system operating against the same threat. In this respect, the definite mathematical method does not compare unfavorably to the war gaming method. The advantages of war gaming in this aspect rest mainly on the fact that the game is built with the

expressed characteristic of ease of replay and this makes it a better vehicle to attain the merits of numerous plays and makes its results more amenable to statistical analysis.

2. Bonus advantages.

The two advantages listed below do not pertain directly to the analytic method itself, but rather to advantages from which the decisionmaker benefits by employing the war gaming method, regardless of the ultimate results or the lack thereof. It should be noticed, however, that these advantages only accrue in the case where the decisionmaker associates himself closely with the game and its builder.

Modeling a complex situation increases one's understanding of the basic structure of the problem. This advantage of modeling, whether the model be mathematical or physical, lies in the fact that the process of construction, by itself, can often lead to the discovery of many underlying and hitherto unknown causes and effects which act in the real world. As the analyst assembles the war game and tries to describe mathematically the action taking place, he is forced to scrutinize the relationships between events and participants in minute detail. He must painstakingly detail each event and interaction. In doing this, he may look at the particular event in a new and critical manner, a look which often breeds fortuitous changes in the way of doing things.

While setting forth the logic of the game, the gamer may notice illogical arrangements of forces or inconsistent procedures which have never been illuminated before. Even if the game cannot solve these inconsistencies, the experience may lead to a necessary reapprasial and constructive future action. Although the true nature of these discover-

ies may be valuable from an educational point of view, the analytic gain should not be overlooked simply because it is not immediately useful. A methodology which does no more than expose errors can be considered as analytically advantagous.

Analytic war gaming may provide a needed link between the civilian analyst and the operational commander. War gaming is a method of tactical and strategic evaluation quite natural to the military officer. In time of peace, or, to be more sophisticated, in time of minimum military involvement, the operational commander employs various techniques to maintain and improve his fighting units. While these techniques have different labels, [1] they may be generally considered as war games in the traditional sense. He has also developed many procedures for planning future action from artificial models, such as; drawing lines on maps, using maneuvering boards, maintaining tactical trainers, canned problems, and other simulation devices.

Concurrently with the renewed effort in the manual war gaming area, there has been an increasing use of mathematical techniques for attacking military problems and clarifying military complexities. Since World War II, the application of operations research methods to military problems has grown continuously, and has become an essential part of all military planning.

The advantage of computer simulated war games to be extolled here is that it may provide the link between these two approaches to military

[1]Fleet exercises, bivouacs, games, training cruises, and numerous joint engagements.

analysis; one of which is natural to the military officer and in which he can comfortably improve his operational competance, and the other approach taken primarily by civilian analysts, researchers, and economists, who are trying to pass on to the military the benefits of their fortes. Rather than have these two avenues to better strategy and tactics at odds with each other, or at best unaligned, the modern analytic war game may provide the best setting in which to bring together these two sciences to the increased good of the entire national defense effort.

3. Disadvantages.

Before discussing the disadvantages of using the computer war gaming technique to solve military problems, it may be informative to decide what is meant by a disadvantage or drawback to a methodology. In this paper, a disadvantage will be taken to be an identification of a problem encountered while using this method, which might not arise if another approach to the problem were used. If the gaming method cannot solve a given problem, this will not be considered a disadvantage, but rather a limitation. If the game is of such a nature so as to appear to solve a problem when it really does not, this is a disadvantage. This chapter will not be explicitly concerned with limitations of the method since many of these have been alluded to previously. Rather, an attempt will be made to point out some of the reasons for the consternation that often arises when the technique is employed to aid the military decisionmaker.

The average game is not easy to follow. It has been suggested in chapter four that the user should read, check, and throughly understand

the internal logic of the war game so that he can be satisfied with the consistency of the results. This is easier to suggest than to accomplish. If the user has been personally involved with the construction of the model, he may be reasonably content. If not, by far the most common situation, he may find it difficult, time consuming, or even impossible to fully understand all the internal mechanisms by which the game proceeds. In this state of affairs, how is he to make good use of the game's revelations? He probably cannot.

Before going further, it is imperative that the gravity of the need for logical validity, to the satisfaction of the decisionmaker, be established. The problem of impressing upon the executive the usefulness of an operations research study is not a new one. The decisionmaker has many justifiable misgivings about mathematical solutions which are, of necessity, abstractions from the actual setting. In many cases, however, when the study is completed, the solution is "obvious", or easily checked and accepted.

Consider two famous operations research studies of World War II vintage: one involving a new procedure for washing mess kits, and the other pointing to a change in the depth setting of a depth charge(17). In each case, the solution could be checked at little risk.

As the operations researcher tackles problems on a higher tactical or strategic scale, he must give the decisionmaker more and more assurance before a change will be made. In war gaming, where the method is most promising when dealing with large and complex military arrangements, suggested changes are not painless to try, and the decisionmaker must act with conviction. A war game in this era may imply that an entire

weapon system is not worth its cost, or that a whole defense system deployment needs to be rearranged.

As the solemnity of the decisions increases and operational checks become more difficult, the need for validation of results becomes mandatory. If this cannot be done, the technique may not be a satisfactory approach to military problems. If the builder works in conditions remote from daily consultation with military opinion, he may fail to construct his internal logic in conformance with the essence of the real world situation, or with the current operational judgment.

One way to beat this drawback is to fully document the game so that the user can trace the logic easier. Unfortunately, experience to date indicates that this may double the time and effort needed to build the game, or require excessive toil after the game has been completed and presented to the user.

<u>One misguided assumption can effect the entire outcome disproportionately</u>. The war gaming method has been cited as advantageous in that it can be used to seek the solution to an entire series of complicated interactions, rather than obtain the result from a summation of factored-out subproblems. With this quality goes an obvious drawback. When going for all or nothing in a solution, one mistaken assumption can result in nothing, and more effort is wasted than if the mistake were made in a small subproblem.

The delicacy needed in choosing assumptions was stressed in chapter two and it may now be clear that an unacceptable assumption anywhere in the game may cause the entire program to be rejected regardless of the [illegible] of the rest of the model. There may be, in

the end, so many objections, reasonable or otherwise, to the assumptions made in the game, that the problem may best be left to a more conservative and well tested method.

Many of these objections arise because, it will be recalled, the war game is distinctive in that it attempts to put down all the relevant happenings and their effects, even those caused by natural and human forces. In doing so, the gamer has exposed his product to an endless stream of criticism, since very few people will agree on a given interpretion of human behavior.

The above disadvantage can be reduced somewhat in scope if the builder consults often with the user, and others knowledgeable in the field, during the construction of the game

<u>The analytic gaming method conflicts with the "judgment of experts" concept.</u> As stated earlier, the war game is a blend, bringing together contributions from the civilian analyst and the field commander. This characteristic, mentioned before as a virtue, may turn out to be a vice if the blending never takes place. The military commander, who must make the final decision, has found that he has to rely heavily on personal judgment and experience; whereas the civilian analyst may sometimes feel that all problems, military or otherwise, can be solved by the application of the scientific method, if the proper techniques are developed.

The war game provides "experience" in an artifical sense and often provides it where it is not attainable in any other way. Is this experience comparable to actual military experience? How can it best be used? Answers to questions of this nature help to decide the proper use of the game method, and whether its employment will ultimately aid or hinder

the decisionmaker.

It is conceivable that war gaming may be used to substitute for actual exercises and become a vehicle for the making of military decisions by nonmilitary personnel. This would appear to be an unfortunate use of a potentially beneficial technique. The gaming method, when used in proper perspective, should be complementary to actual military experience and supplement the "judgment of experts", rather than replace it.

The product may never "sell". This last objection is aimed primarily at the practice of building "all purpose" or general war game models. It has been emphasized throughout this thesis that the objective of the game must be firmly established in order to make logical assumptions, and to make best use of the results. It may be possible to modify a game, built for one purpose, to make it useful for another purpose, but this amounts to a new war game using some of the old modeling techniques.

Most operations research studies are constructed around the problem to be solved and this is generally true of studies utilizing the simulation device. However, there seems to be an urge on the part of some compulsive model builders to put together games and then seek a use for them. This does not seem to be the most effective manner of applying the technique to military situations.

Rather than describing reality in mathematical form, the pursuers of this approach are trying to make reality fit a preconceived model with minimum change in the model. This tactic can not only lead to strained assumptions, but could also have the effect of solving problems which the decisionmaker does not have, while neglecting the ones

that he is grappling with.

Conversations with military planners, faced with problems which may be solved by the use of war gaming, indicate that they prefer to develop their own models rather than adapt to a model already in existence. If this a universial feeling, then games constructed for general usage and not related to a specific military problem may be consigned to the shelf. The talents consumed in such efforts may never yield the potential benefits to the decisionmaker.

The military services, if they are to reap the benefits of this new and powerful analytic technique, must invade the privacy of the civilian model builders and suggest objectives, while at the same time providing accurate data with which the researcher can channel his efforts toward a realizable end and then "sell" his product to an appreciative customer.

REFERENCES AND SELECTED BIBLIOGRAPHY

1. Adams, R. H. and Jenkins, J. L. "Simulation of Air Operations with the Air Battle Model," JORSA, Vol. 8, No. 5, October 1960.

2. Andlinger, G. R. "Business Games-Play One," Harvard Business Review, March-April 1958.

3. Antosiewicz, H. A. "Analytic Study of War Games," Naval Research Logistics Quarterly, Vol. 2, No. 3, September 1955.

4. Bellman, R., et al. "On the Construction of a Multi-Stage, Multi-Person Game," JORSA, Vol. 5, No. 4, August 1957.

5. Biser, E. and Meyerson, M. "The Application of Design of Experiments and Modeling to Complex Weapons Systems," JORSA, Vol. 5, No. 2, April 1957.

6. Bowker, A. H. and Lieberman, G. J. Engineering Statistics. Prentice-Hall, 1959.

7. Clark, C. E. "Importance Sampling in Monte Carlo Analysis," JORSA, Vol. 9, No. 5, October 1961.

8. Conway, R. W., et al. "Some Problems of Digital Systems Simulation," Management Science, Vol. 6, No. 1, October 1959.

9. Cushen, W. E. "War Games and Operations Research," Philosophy of Science, Vol. 22, No. 4, October 1955.

10. Galler, B. A. The Language of Computers. McGraw-Hill, 1962

11. Harling, J. "Simulation Techniques in Operations Research-A Review," JORSA, Vol. 6, No. 3, June 1958.

12. Kahn, H. and Mann, I. "War Gaming," The RAND Corp., P-1167, July 1957.

13. Livermore, W. R. The American Kriegspiel. Clarke, 1898.

14. McDonald, J. D. and Ricciardi, F. M. "The Business Decision Game," Fortune, March 1958.

15. McHugh, F. J. "Fundamentals of War Gaming," The United States Naval War College, 2nd. ed., November 1961.

16. Mood, A. M. "War Gaming as a Technique of Analysis," The RAND Corp., P-899, September 1954.

17. Morse, P. M. and Kimball, G. E. Methods of Operations Research. The Technology Press, 1951

18. Paxson, E. W. "War Gaming," The RAND Corp., RM-3489-PR.

19. Quade, E. S. (ed.). "Analysis for Military Decisions," The RAND Corp., R-387-PR, March 1964.

20. Rich, R. P. "Simulation as an Aid in Model Building," JORSA, Vol. 3, No. 1, February 1955.

21. Resume' of War Games Types and Terms. OPNAV Instruction 03000 7, 12 February 1960. (Confidential).

22. Sayre, F. Map Maneuvers and Tactical Rides, Army Service School Press, 1910.

23. Strauss, W. J. "The Nature of Operations Research," JORSA, Vol. 8, No. 5, June 1960.

24. Symposium on Monte Carlo Methods. H. A. Meyer (ed.). Wiley, 1956.

25. The International Dictionary of Applied Mathematics. Van Nostrand, 1960.

26. Thomas, C. J. and Deemer, W. L. "The Role of Operational Gaming in Operations Research," JORSA, Vol. 5, No. 1, February 1957.

27. Wallis, W. A. and Roberts, H. V. Statistics: A New Approach. The Free Press, 1956.

28. Washington Operations Research Council. First War Gaming Symposium, Proceedings. J. L. Overholt (ed.) November 1961.

29. Watson, P. B. and Abernathy, T. R. "War Gaming with a Digital Computer-A Discussion and an Example," Unpublished Master's thesis, United States Naval Postgraduate School, 1961.

30. Weiner, M. G. "War Game Methodology," The RAND Corp., RM-2413, July 1959.

31. ---------- "An Introduction to War Games," The RAND Corp., P-1773, August 1959.

32. Young, J. P. "A Survey of Historical Developments in War Games," Operations Research Office, Johns Hopkins University, Staff Paper 98, August 1959.

33. Zimmerman, R. E. "A Monte Carlo Model for Military Analysis," Operations Research for Management, Vol. II, Johns Hopkins Press, 1956.

Note: JORSA--Journal of the Operations Research Society of America.

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